



Evaluation of a Multi-mOdel, Multi-cOnstituent CHEMical data assimilation framework (MOMO-Chem) for tropospheric chemical reanalysis

+

new GEOS-Chem-EnKF system!

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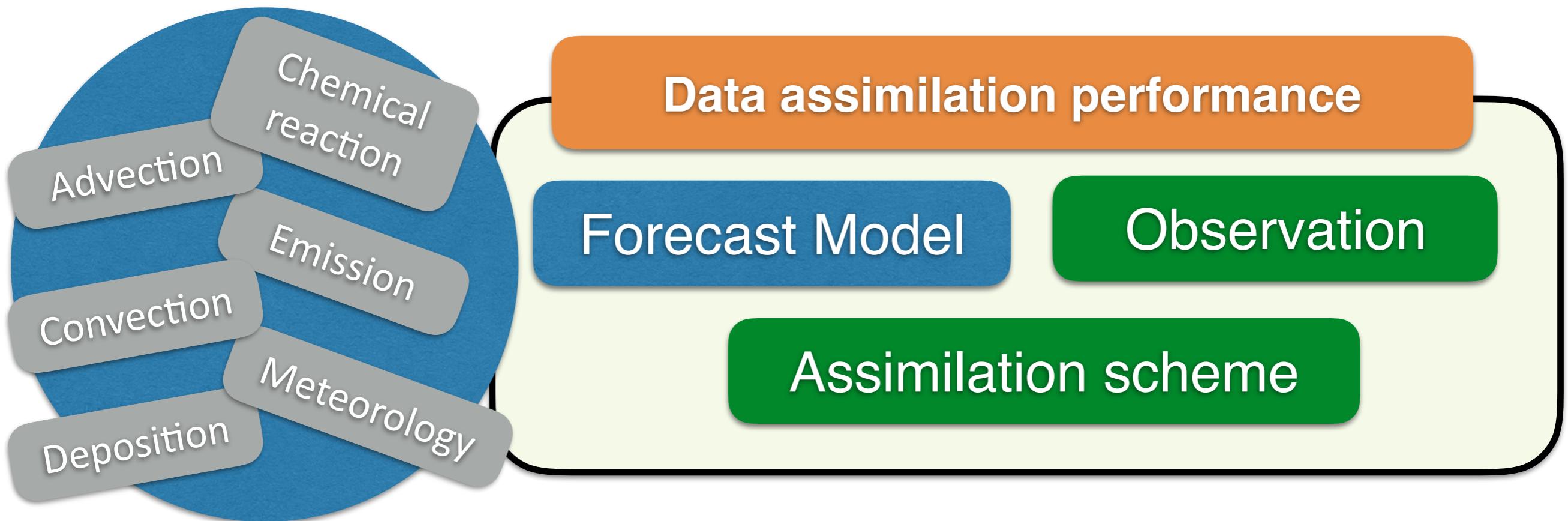
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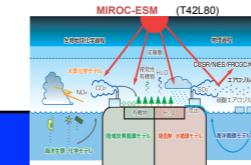
Tropospheric chemistry data assimilation

Applications: Chemical reanalysis, emission estimation, air quality forecasting, OSSEs



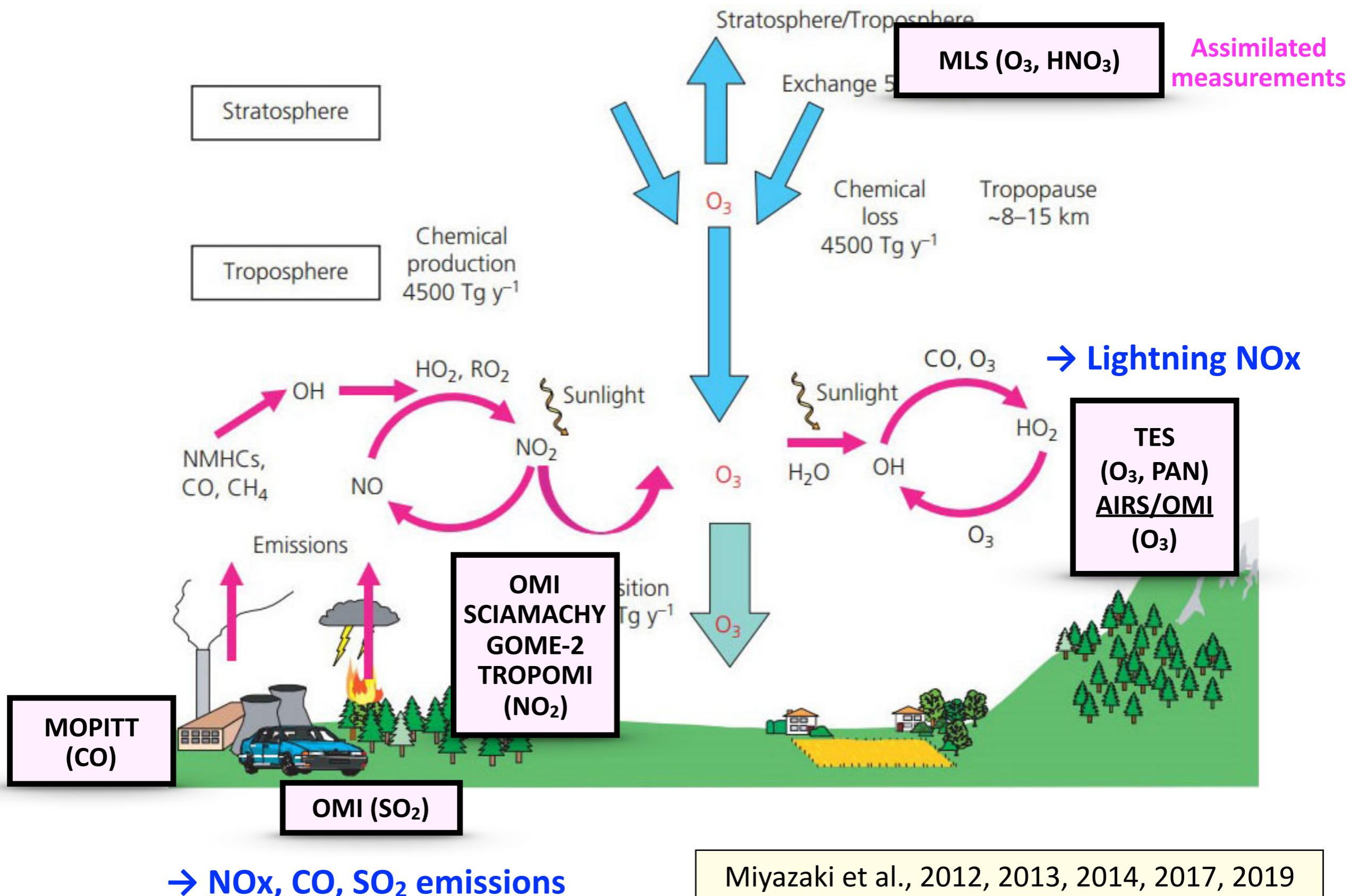
Multi-model chemical data assimilation using a common EnKF approach

- investigate the importance of forecast model performance
- provide multi-model integrated data assimilation analysis



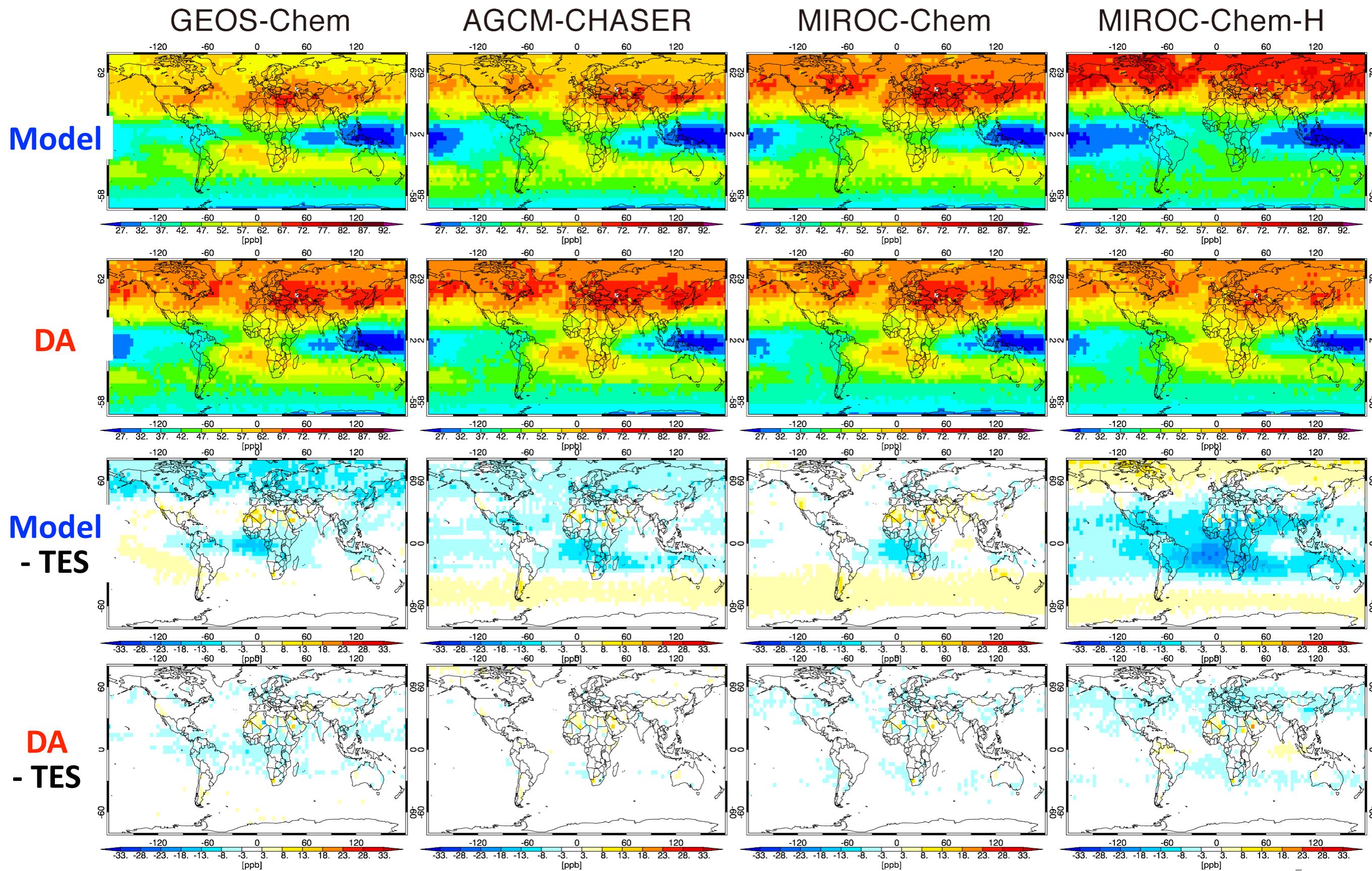
	1. GEOS-Chem	2. AGCM-CHASER (TCR-1)	3. MIROC-Chem	4. MIROC-Chem-H (TCR-2)
Horizontal resolution	2°x2.5°	2.8°x2.8°	2.8°x2.8°	1.1°x1.1°
Vertical resolution	47 layers to 0.1 hPa (hybrid)	32 layers to 4 hPa (sigma)	32 layers to 4 hPa (hybrid)	32 layers to 4 hPa (hybrid)
Forecast model	GEOS-Chem v9 (adjoint v35)	CCSR/NIES/FRCGC AGCM-CHASER	MIROC-Chem	MIROC-Chem
Chemistry	43 species, 318 reactions	47 species, 88 reactions	92 species, 262 reactions	92 species, 262 reactions
Met data	GEOS-5	Nudged to NCEP-2	Nudged to ERA-Interim	Nudged to ERA-Interim
A priori emissions	EDGAR, NEI2008, RETRO, GFED2,	EDGAR 4.2, GFED 3.1, GEIA	EDGAR 4.2, GFED 3.1, GEIA	HTAP2, GFED4, GEIA
Assimilated measurements	OMI, SCIAMACHY (DOMINO2), TES (v5), MOPITT (v6 NIR), MLS (3.3)	OMI, SCIAMACHY (DOMINO2), TES (v5), MOPITT (v6 NIR), MLS (3.3)	OMI, SCIAMACHY (DOMINO2), TES (v5), MOPITT (v6 NIR), MLS (3.3)	OMI (QA4ECV, PCA), SCIAMACHY (QA4ECV), TES (v6), MOPITT (v7J), MLS (v4.2)
Assimilated species	O ₃ , CO, NO ₂ , HNO ₃	O ₃ , CO, NO ₂ , HNO ₃	O ₃ , CO, NO ₂ , HNO ₃	O ₃ , CO, NO ₂ , SO ₂ , HNO ₃
State vector	Concentrations of 43 species + emissions (NO _x , CO, LNO _x)	35 species + emissions (NO _x , diurnal variability, CO, LNO _x)	35 species + emissions (NO _x , diurnal variability, CO, LNO _x)	35 species + emissions (NO _x , diurnal variability, CO, SO ₂ , LNO _x)
Model reference	Henze et al. (2007)	Sudo et al. (2002)	Watanabe et al. (2011)	Sekiya et al. (2018)
DA reference	Miyazaki et al., to be submitted	Miyazaki et al. 2012a,b 2013, 2014, 2015	Miyazaki et al. 2017	Miyazaki et al. 2018a & paper in prep., Kanaya et al., 2019, Thompson et al., 2019

Multi-constituent chemical data assimilation



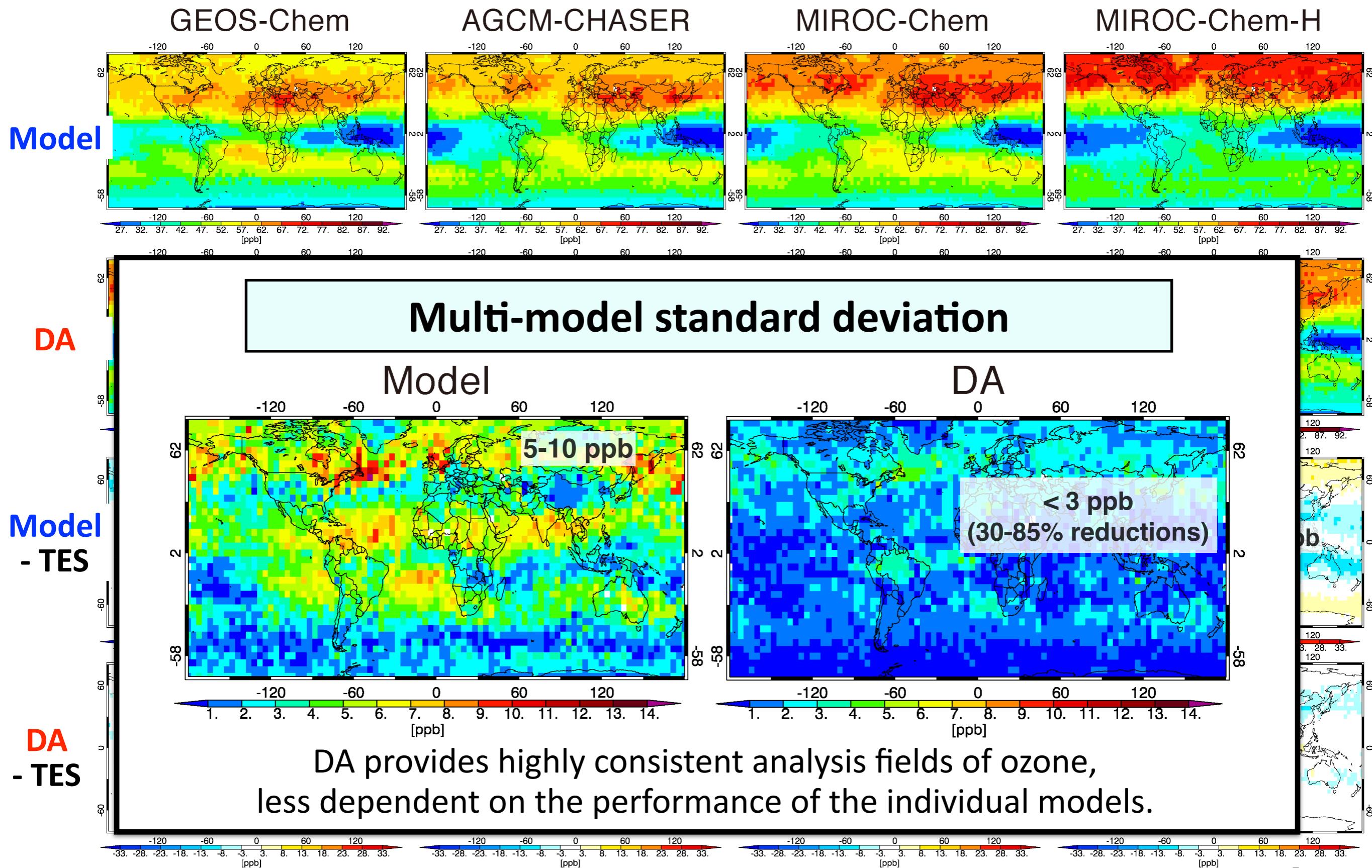
vs TES ozone (assimilated)

Ozone, 510 hPa, annual mean



vs TES ozone (assimilated)

Ozone, 510 hPa, annual mean



vs WOUDC ozonesonde

Assimilation
Model



Multi-model
mean/spread

55S–15S

15N–55N

55S–15S, 500–200hPa

15N–55N, 500–200hPa

500–200
hPa

Ozone [ppb]

Month

Annual mean bias
Model: 10.6 ± 7.6
Assim: 1.1 ± 2.3

- OBS
- GEOS-Chem
- AGCM-CHASER
- MIROC-Chem
- MIROC-Chem-H

850–500
hPa

Ozone [ppb]

Month

Model: -2.5 ± 2.5
Assim: 1.6 ± 1.1

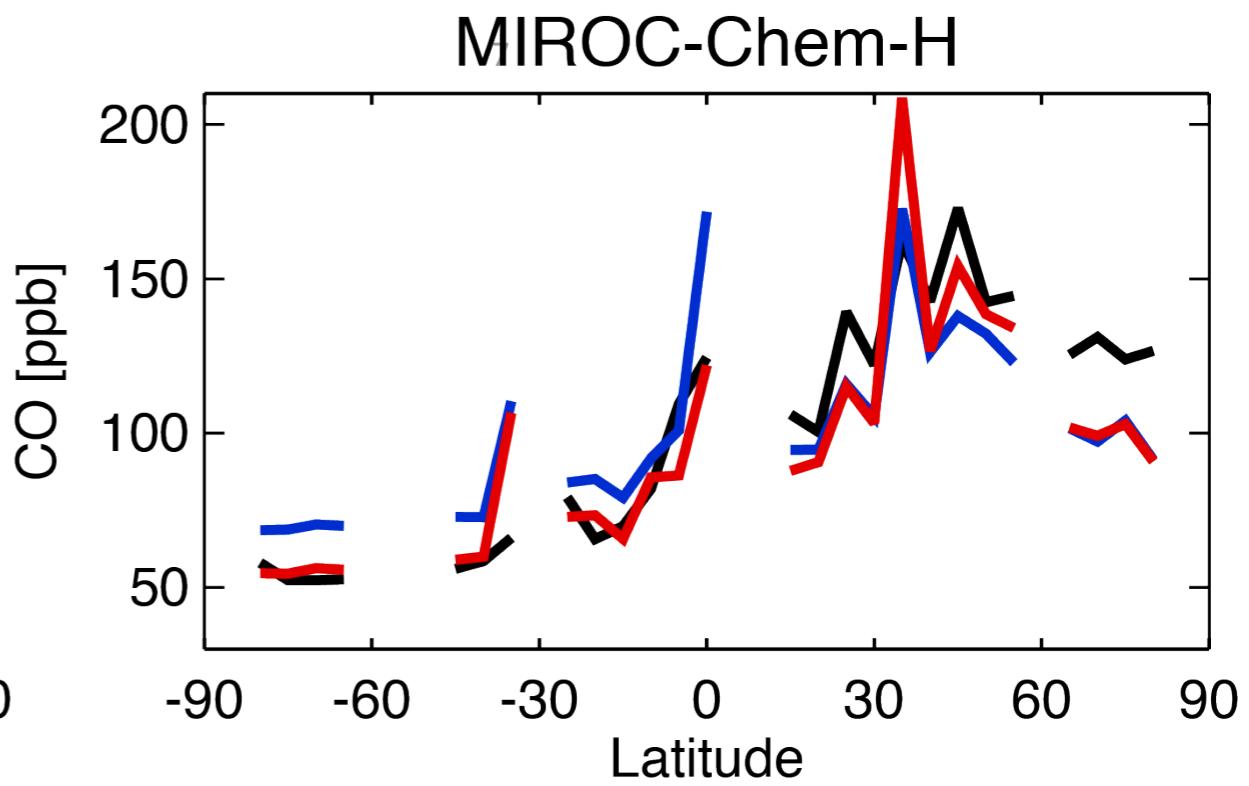
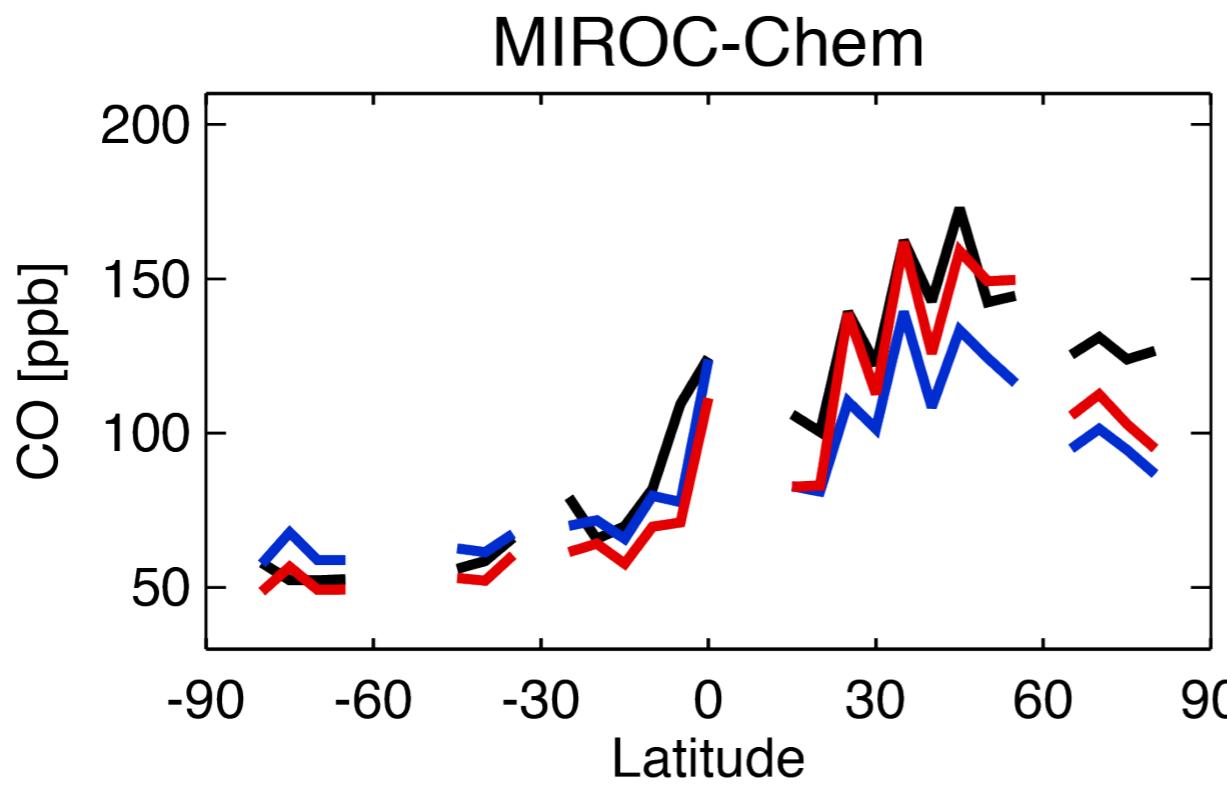
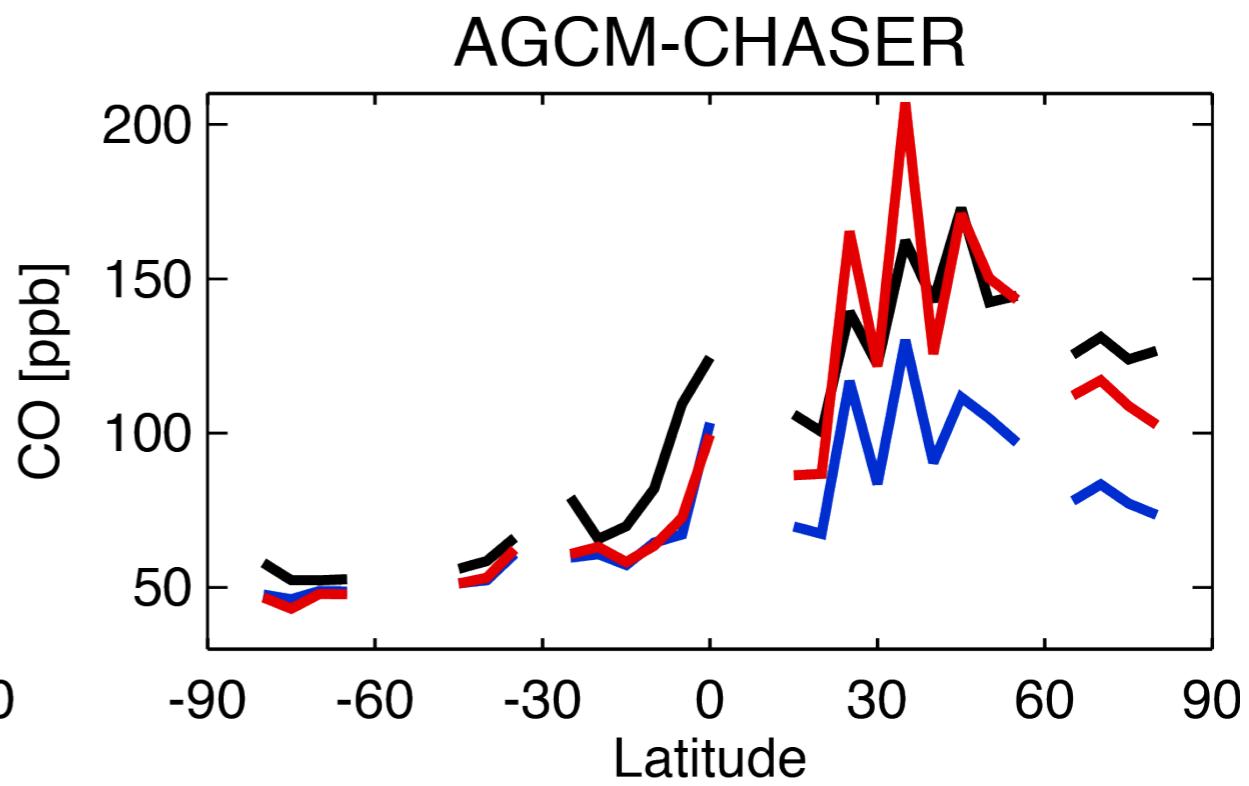
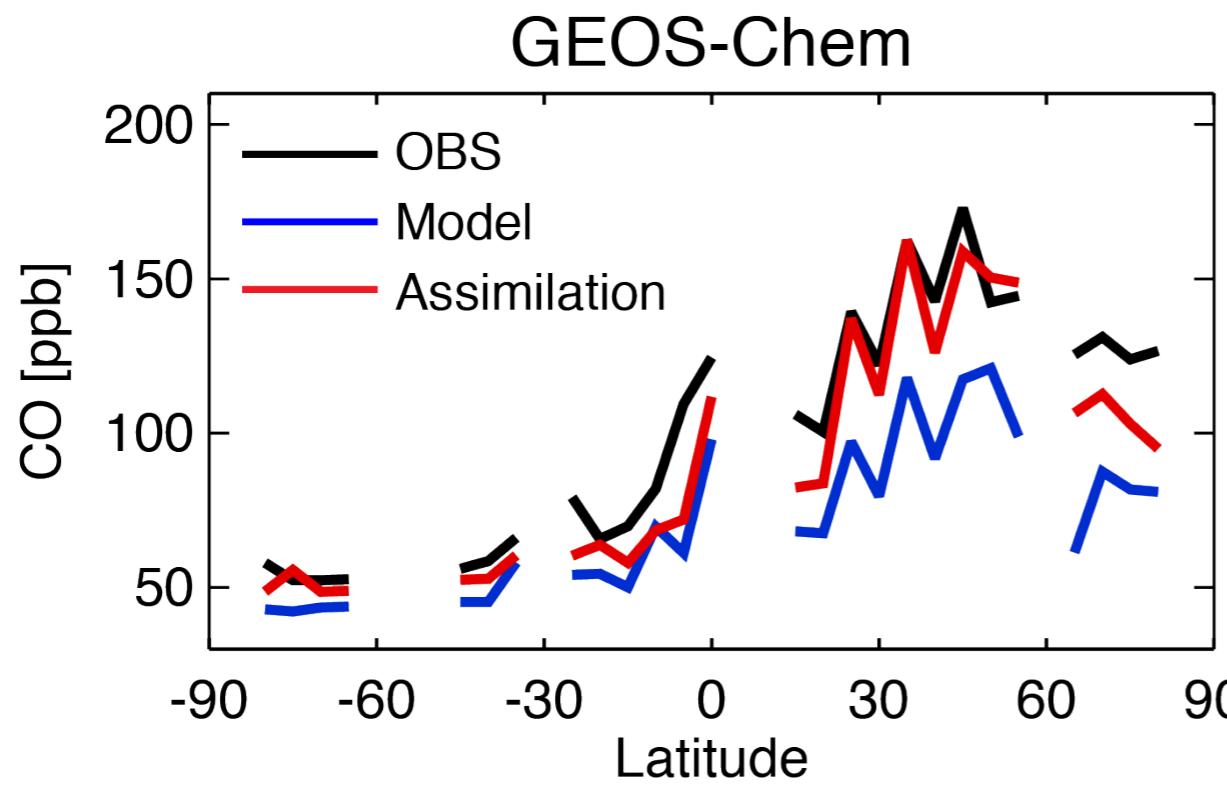
55S–15S, 850–500hPa

15N–55N, 850–500hPa

DA improved the agreements with ozon sondes and the multi-model consistency

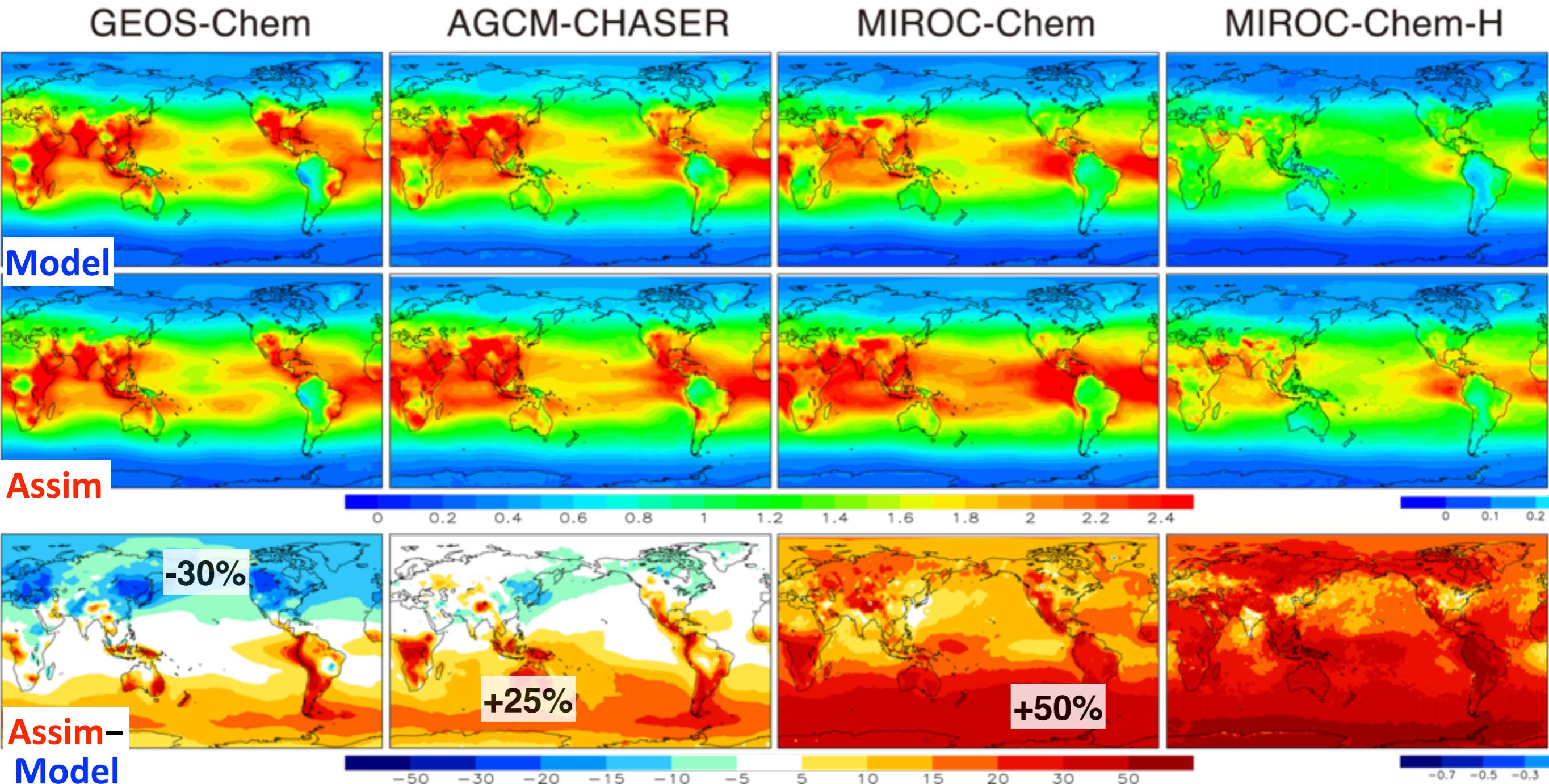
Annual mean bias reductions: by 39–97% for the globe

vs Surface CO (WDCGG)



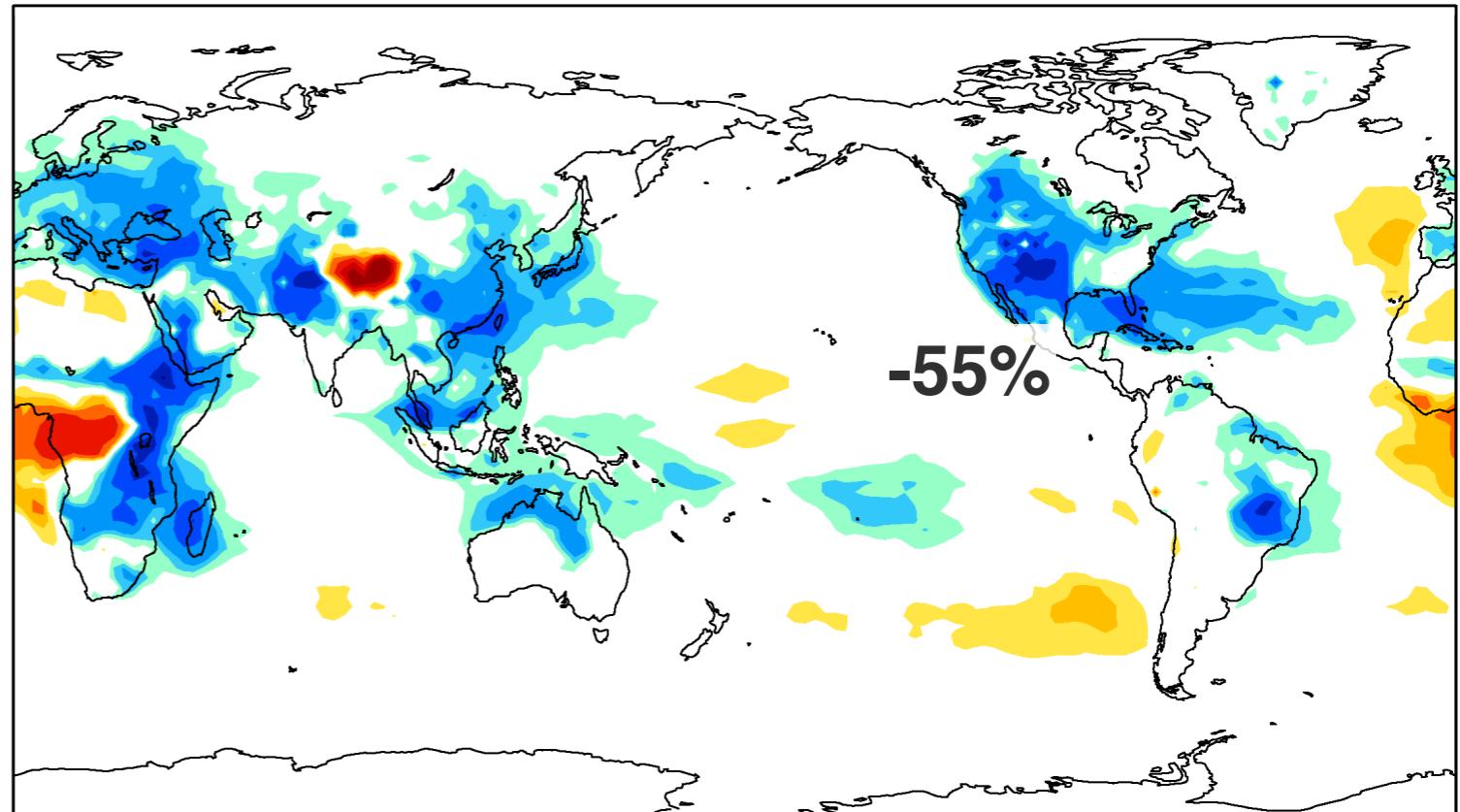
Removed negative model biases (by 25–70 ppb in NH and 10–60 ppb in the tropics)
Insufficient correlations in the tropics: short DA windows = 2 H except for GC (6H)

Tropospheric OH: Annual mean



Data assimilation modified global OH distributions in all the systems considerably, associated with changes made to ozone, CO, and NOx.

**Relative changes [%]
in multi-model OH spread
by data assimilation**



NH-SH OH ratio

9

	GEOS-Chem	AGCM-CHASER	MIROC-Chem	MIROC-Chem-H	Multi-model
Model	1.30	1.36	1.29	1.31	1.29 ± 0.03
Assim	1.16	1.23	1.18	1.21	1.18 ± 0.03

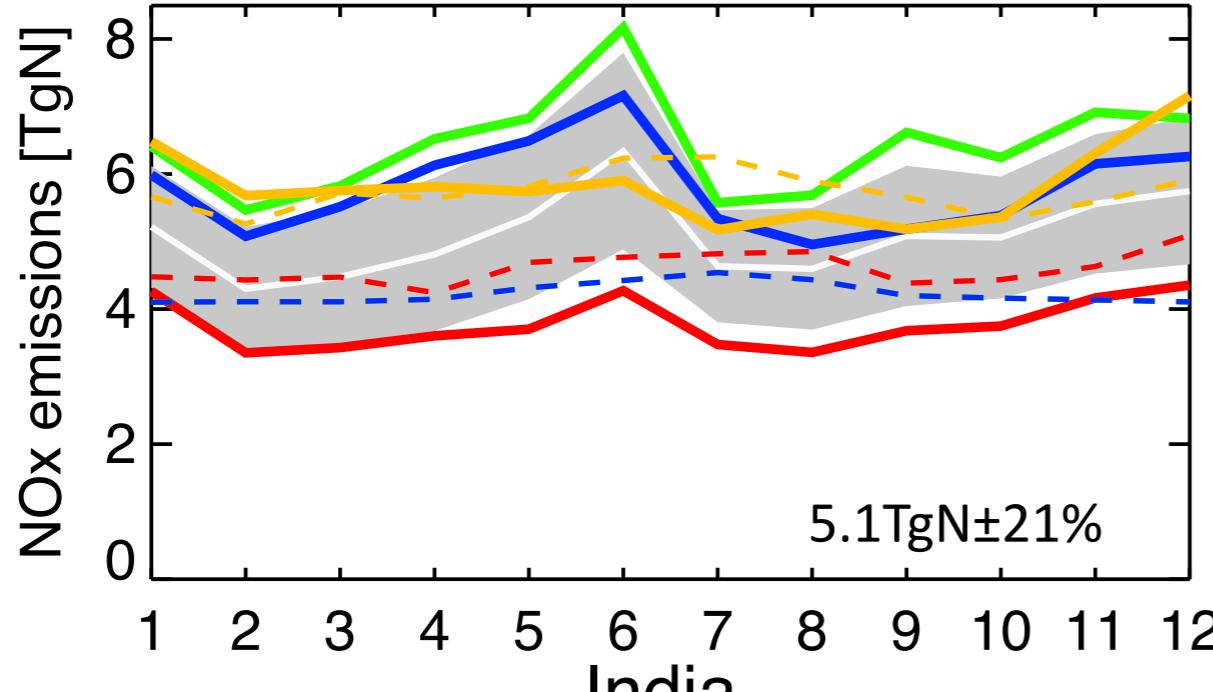
The significant changes in OH are important in propagating the observational information and modulating the chemical lifetimes of many species

NO_x emissions

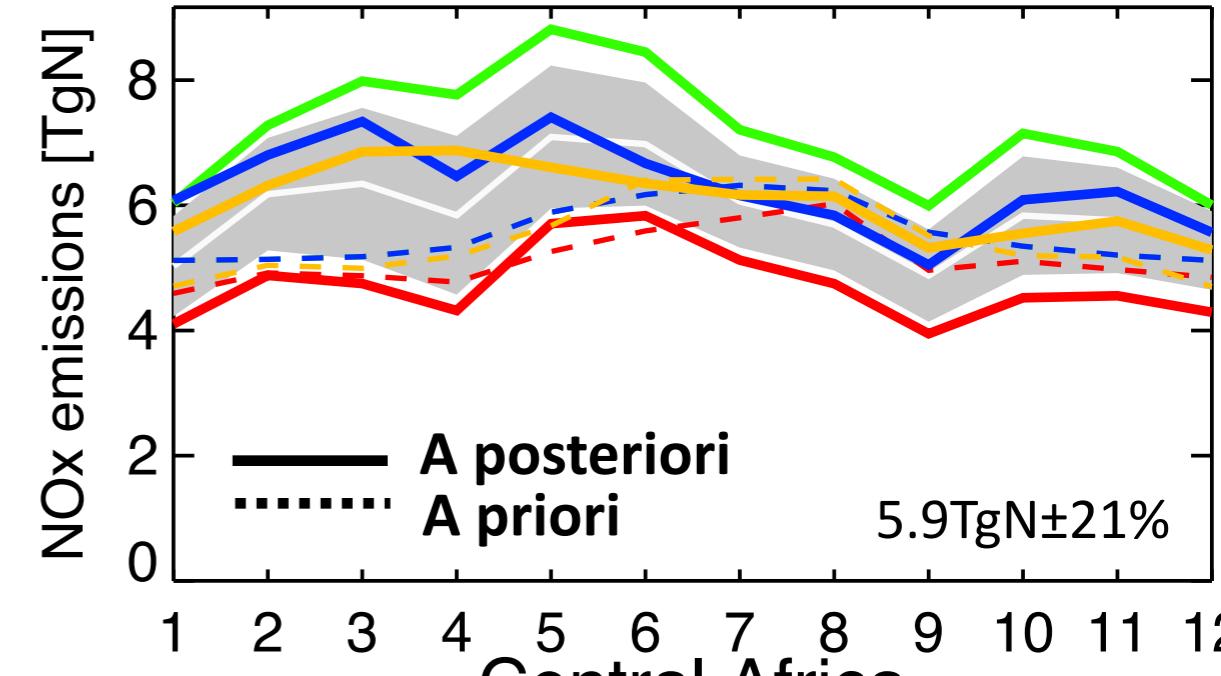
Global total emissions: from 39.1TgN (GC) to 51.9TgN (CHASER)

Multi-model SD: 13–31% for industrialized areas and 4–21% for BB areas

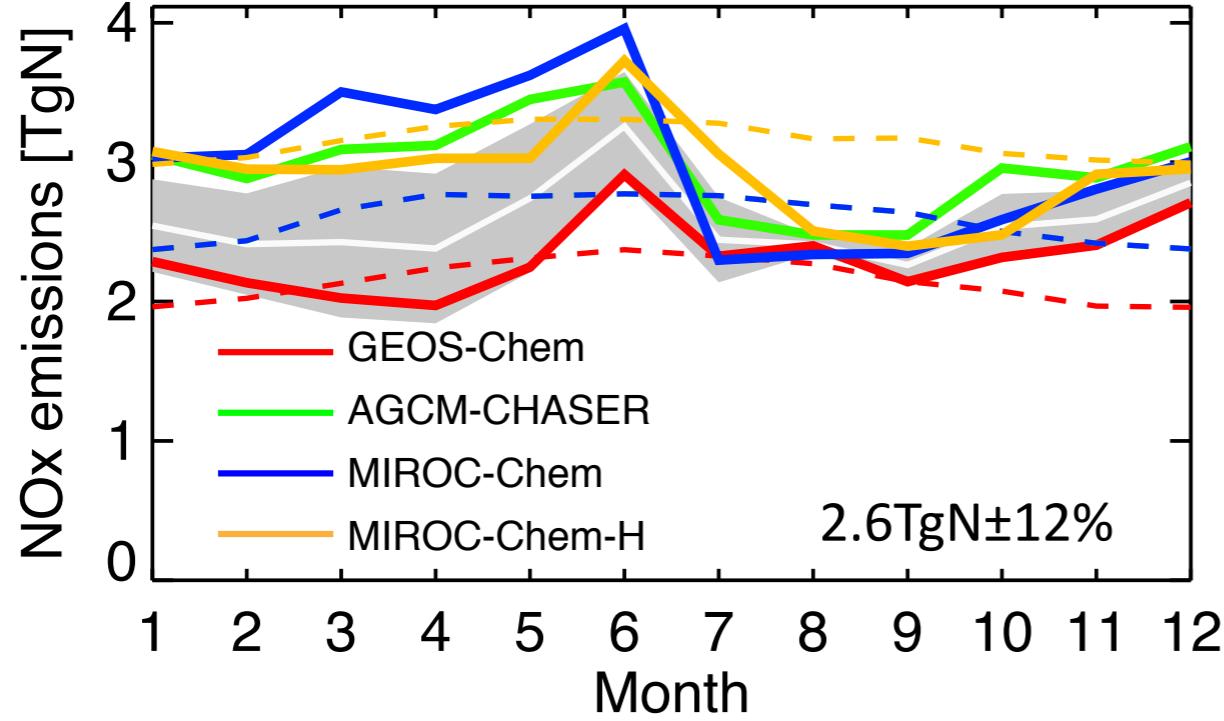
East China



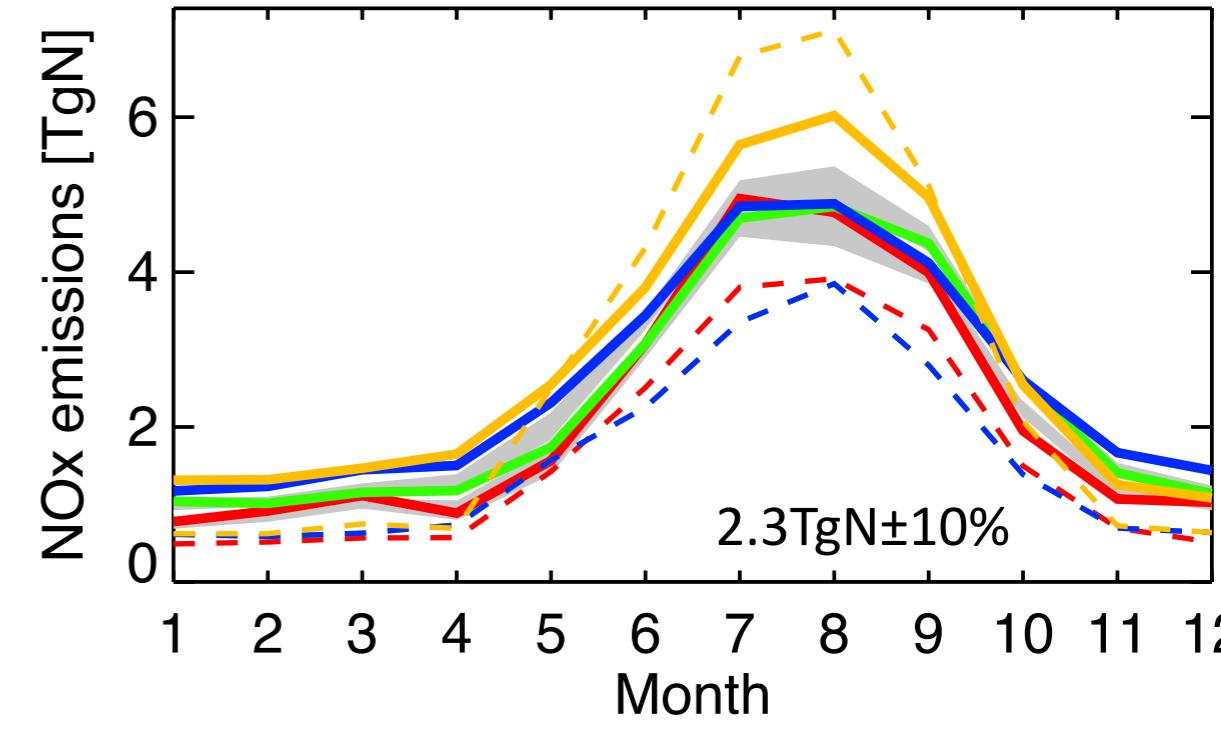
USA



India



Central Africa



Commonly suggested potential problems in the bottom-up inventories:

summertime soil emissions (too low), open BB emissions in spring over India (missing),
BB emissions over South America (too high) and central Africa (too low)

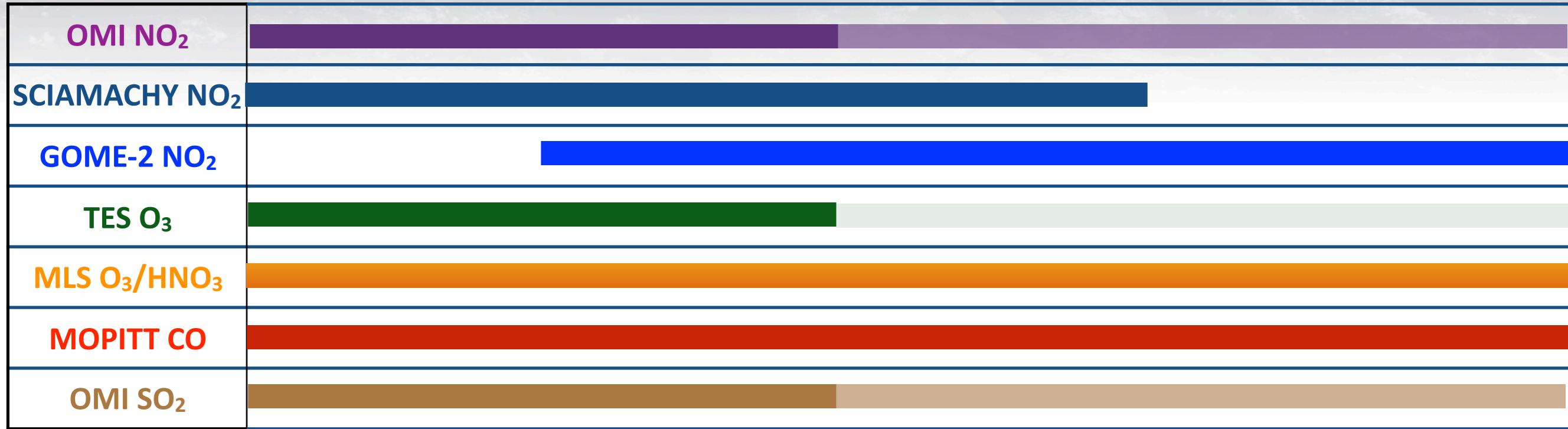


Multi-model decadal chemical reanalyses

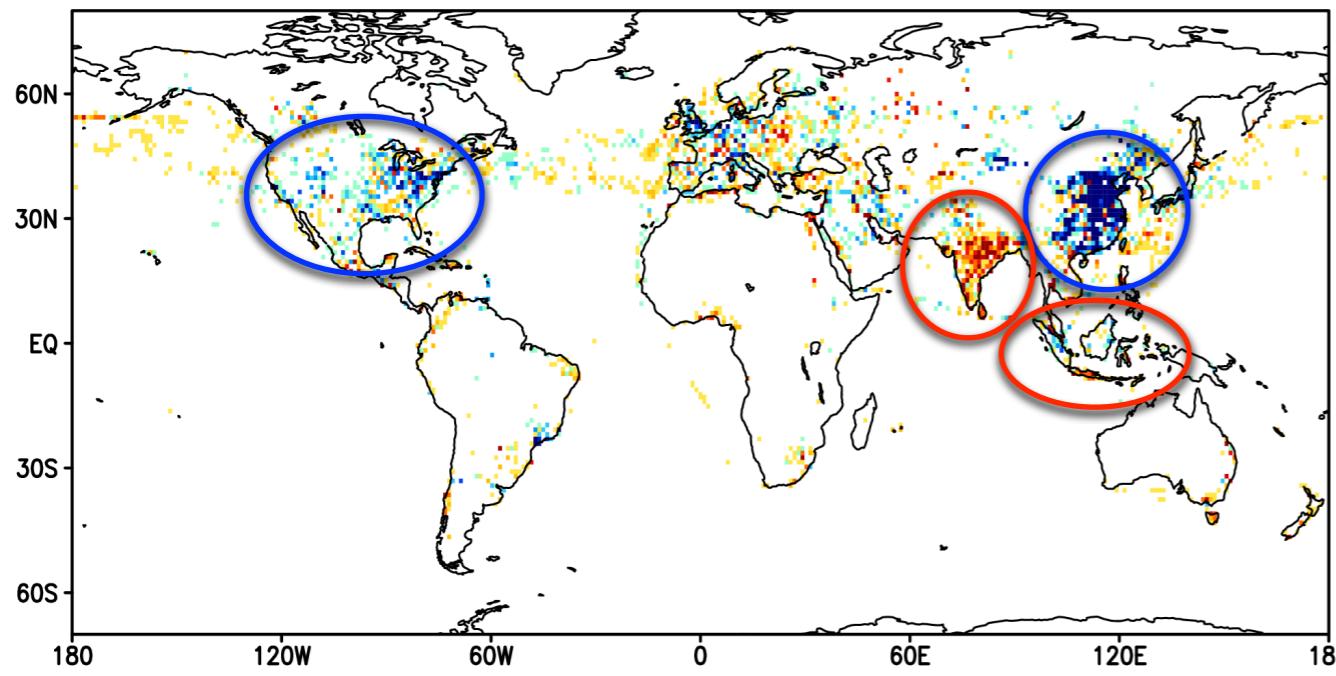
2005

2010

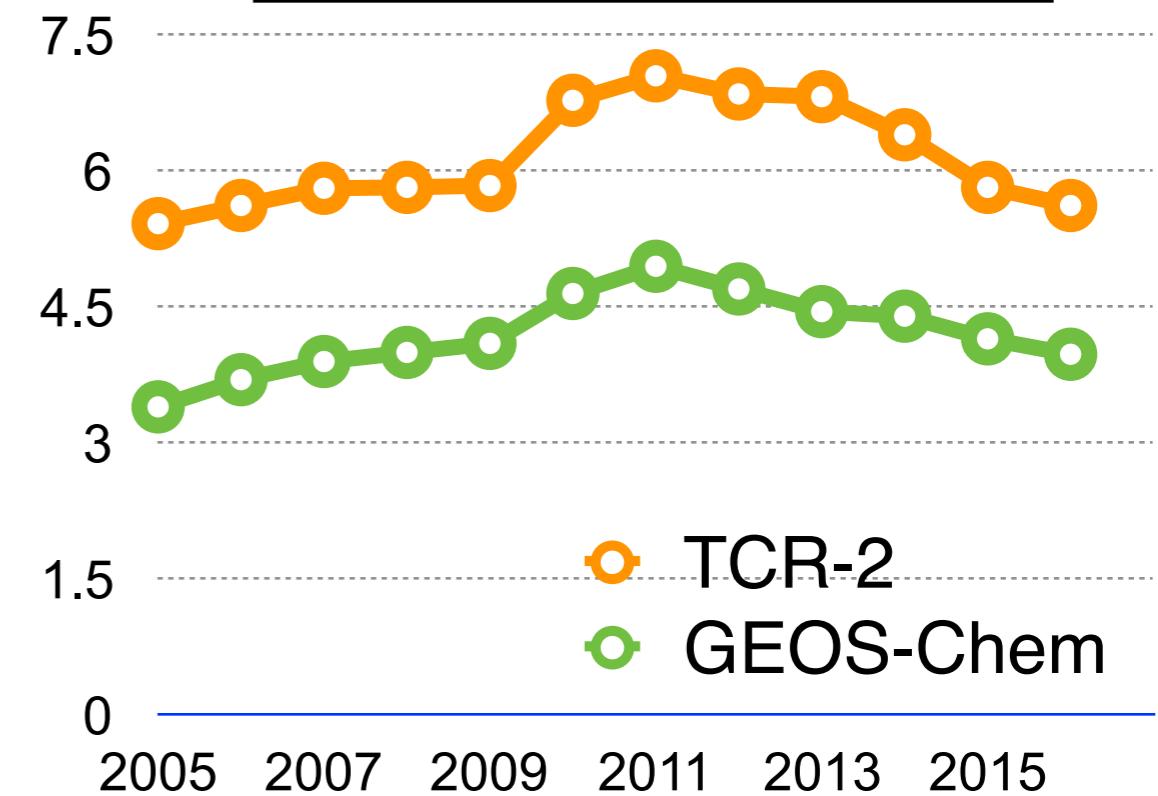
2018



**NOx emission changes
from 2010-2014 to 2015-2017**



NOx emissions: China





Conclusion

- We introduced the MOMO-Chem framework can integrate a portfolio of forward chemical transport models in a state-of-the-art EnKF DA system.
- This system is capable of simultaneously optimizing both chemical concentrations and emissions of multiple species through ingestion of a suite of measurements (ozone, NO₂, CO, HNO₃) from multiple satellite sensors.
- The MOMO-Chem framework provides integrated unique information on the tropospheric chemistry system including precursor's emissions, that are less dependent on the characteristics of individual models.

(Miyazaki, Bowman et al., to be submitted)

Current & future applications at JPL:

- Decadal variations, TROPOMI multi-constituent assimilation, multi-reanalysis comparisons, evaluations of satellite retrievals and models, AQ-GHG synergies (CMS-Flux), comparisons with 4D-VAR, *GCHP-EnKF*, *WRF-GC-EnKF*

We welcome collaborations!